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Process enhancement and database support for vehicle operational readiness reporting

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THESIS

PROCESS ENHANCEMENT AND DATABASE SUPPORT FOR VEHICLE OPERATIONAL READINESS REPORTING

by

Russell H. Menko

December 2004

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ABSTRACT (maximum 200 words)

The U.S. Army uses a Unit Readiness Index to track the combat readiness of systems. The Unit Readiness Index relies on the accuracy of automated and manual testing of the hardware and related software of the Line Replaceable Units (LRUs) that comprise the system. These tests are based on a GO/NOGO scenario. When an LRU fails, vehicle commanders, and commanders up the chain of command, can override the failure and continue with a mission. Overriding the NOGO recommendations produces a false combat readiness status for the unit, and creates a number of problems related to unit combat decisions as well as logistical support. This thesis introduces a new process for more effectively tracking combat readiness. It outlines some of the problems associated with the current GO/NOGO scenario and examines the current tests, artifacts and data available from the current process. It proposes an additional Report process and shows how this new process will eliminate the readiness tracking problems associated with the GO/NOGO scenario. It also presents the design of a Vehicle Database and Master Fault Database to support the proposed process, and presents several sample reports generated from this Master Fault Database.

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PROCESS ENHANCEMENT AND DATABASE SUPPORT FOR VEHICLE OPERATIONAL READINESS REPORTING

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requirements for the degree of

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ABSTRACT

The U.S. Army uses a Unit Readiness Index to track the combat readiness of systems. The Unit Readiness Index relies on the accuracy of automated and manual testing of the hardware and related software of the Line Replaceable Units (LRUs) that comprise the system. These tests are based on a GO/NOGO scenario. When an LRU fails, vehicle commanders, and commanders up the chain of command, can override this and continue with a mission. Overriding the NOGO recommendations produces a false combat readiness status for the unit, and creates a number of problems related to unit combat decisions as well as logistical support. This thesis introduces a new process for more effectively tracking combat readiness. It outlines some of the problems associated with the current GO/NOGO scenario and examines the current tests, artifacts and data available from the current process. It proposes an additional Report process and shows how this new process will eliminate the readiness tracking problems associated with the GO/NOGO scenario. It also presents the design of a Vehicle Database and Master Fault Database to support the proposed process, and presents several sample reports generated from this Master Fault Database.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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ACRONYMS AND ABBREVIATIONS

BIT .... Built-In Test
CID .... Commander's Integrated Display LRU
CJCS .... Chairman, Joint Chiefs of Staff
DID .... Driver's Integrated Display LRU
DSESTS .... Direct Support Electrical System Test Set
FCEU .... Fire Control Electronic Unit LRU
FIT .... Fault Isolation Test
FMC .... Fully Mission Capable
GCDP .... Gunner's Control and Display Panel LRU
GDLS .... General Dynamics Land Systems
GSORTS .... Global Status of Resources and Training System
HEU .... Hull Electronic Unit LRU
HPDU .... Hull Power Distribution Unit
H/TEU .... Hull/Turret Electronic Unit LRU
IVIS .... Inter-Vehicle Information System
PC/ASORTS .... Personal Computer/Army Status of Resources and Training System
LRU .... Line Replaceable Unit
MAE .... Mission Accomplishment Estimate
MTP .... Manual Test Procedure
NextGen .... Next Generation Software Engineering Center
NMC .... Non-Mission Critical
NMC .... Not Mission Capable
RIDB .... Readiness Integrated Database
RIU .... Radio Interface Unit LRU
RPC .... Remote Power Control
SMI .... Soldier-Machine Interface
SRU .... Shop Replaceable Unit
S/SDD .... System/Segment Design Specification

ST .... Self Test
TC .... Tank Commander
TP .... Troubleshooting Procedure
TEU .... Turret Electronic Unit LRU
URI .... Unit Readiness Index
USR .... Unit Status Report

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I. INTRODUCTION

A. DESCRIPTION OF PROBLEM

The Army uses the Unit Readiness Index (URI), described in detail in Chapter II, to evaluate combat readiness. To make this thesis manageable, we shall focus our discussion on a single platform, the Abrams M1A2 Main Battle Tank, although the URI applies across all platforms.

For the Abrams M1A2 Main Battle Tank, the hardware portion of each Line Replaceable Unit (LRU) undergoes a continuous automated self-test (ST). When hardware fails, crewmembers normally perform an intrusive Built-In Test (BIT). Continued failure results in having the hardware undergo an even more rigorous Fault Isolation Test (FIT). The software for all three sets of tests resides in each LRU.

The Army uses the phrase “hardware” to describe an LRU; in reality, an LRU consists of a hardware component and a corresponding software component. If an LRU fails, no differentiation is made between the two components. A failed LRU affects the readiness of the vehicle, which in turn affects the readiness of the vehicle’s unit. A tank out of commission affects readiness up the chain of command through the Division level. Figure 1 depicts a typical tank command structure. Figure 2 shows the LRUs contained in the M1A2 (Ronald Siegel 1999). Not all LRUs have software resident within them; Figure 3 depicts the architecture for the LRU components in a tank that contain software (GDLS M1A2 SDP 2003).

Test results of an LRU are classified as either GO or NOGO. When it is NOGO, the LRU must be replaced, or the entire vehicle is considered NOGO. A potential major problem is created when test results are overridden and failures are not addressed. A vehicle’s commander can override the test results, which typically occurs when the failure is examined and determined to be in a non-mission critical area. Reported failures can also be overridden up the chain of command at the Company or Battalion level. A vehicle declared out of commission affects the operational readiness of both the unit and the commands of which the unit is a member.

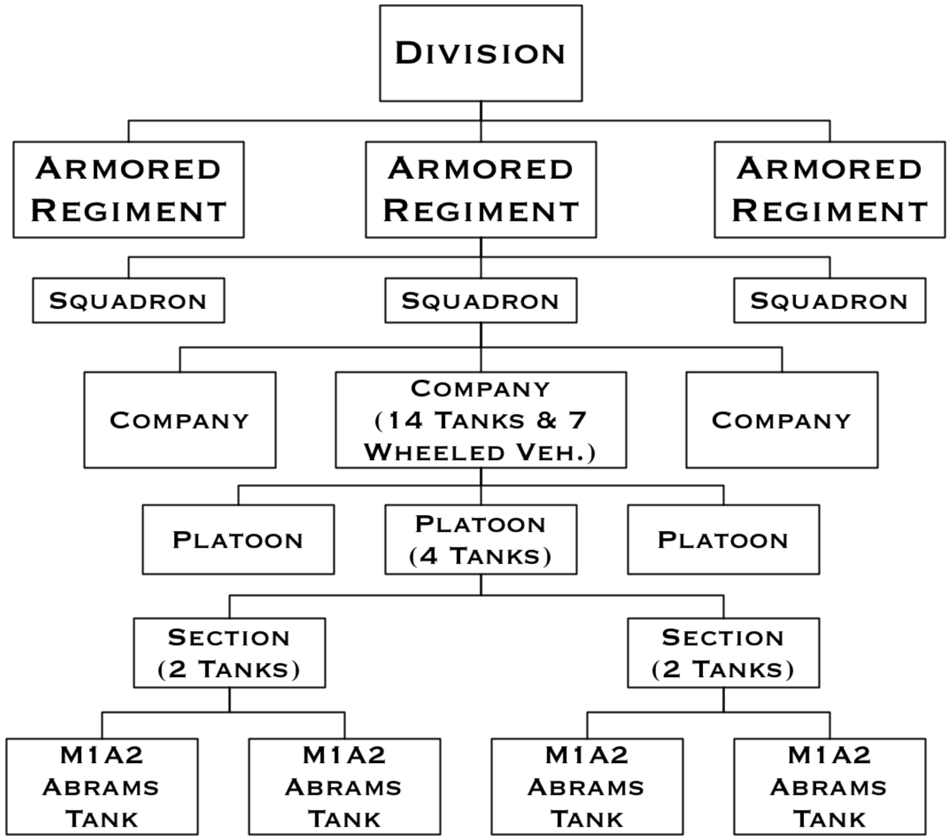

Figure 1 Tank Command Structure

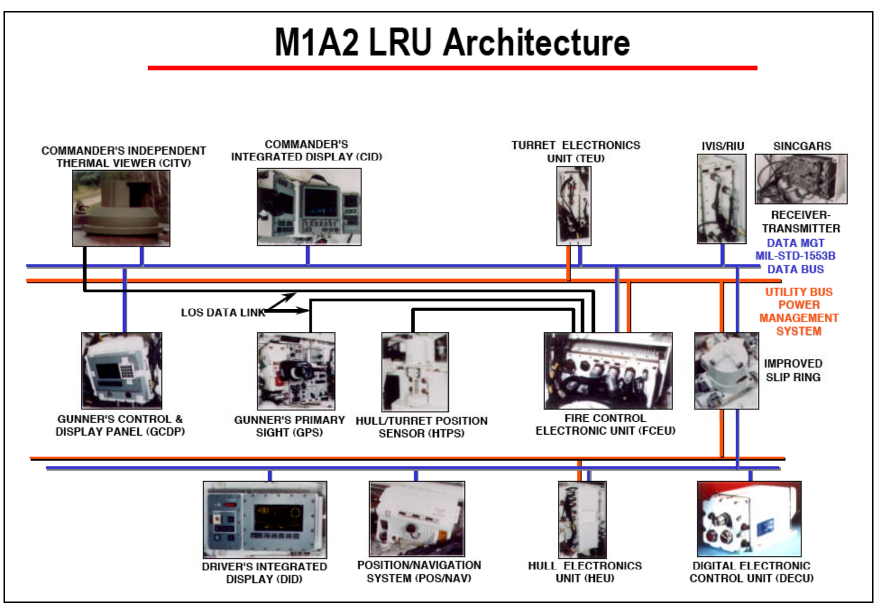

Figure 2 M1A2 LRU Architecture

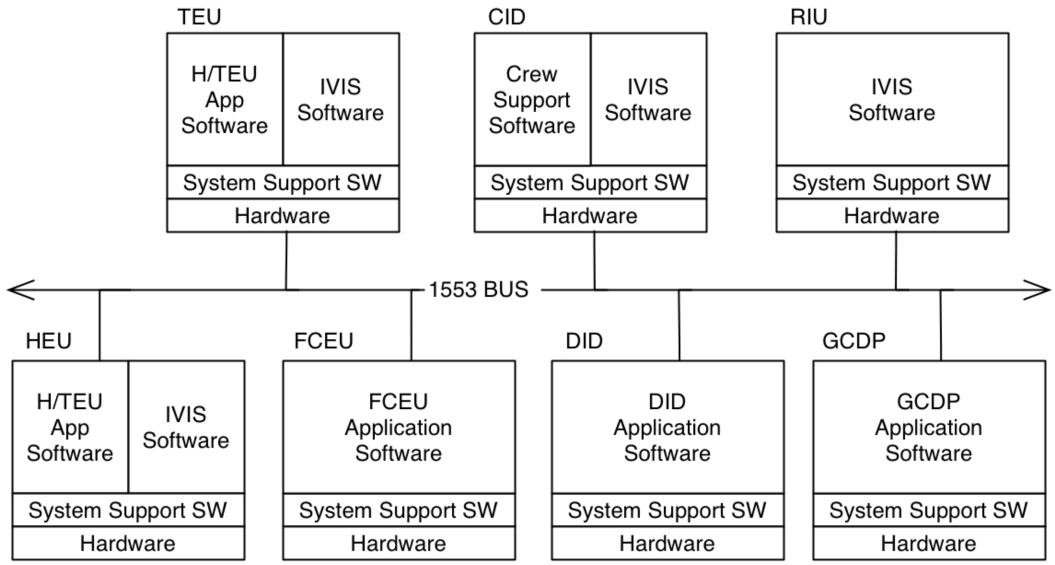

Figure 3 M1A2 Software Architecture

There are many good reasons for overriding failures. For example, during several conversations with former Tankers, they all stated they would not want to take the time to enter information on failures while they were in Combat Mode. Overriding a failure should only delay responding to the failed test. Overriding a readiness rating on a piece of hardware, for any reason, has numerous ramifications, as described in the following paragraphs:

Invalid Test. If the same test is failing across multiple units, the test may be bad. Not reporting it will increase the likelihood it will never get corrected. Furthermore, ignoring a NOGO because the crew thinks the test may be reporting an invalid failure may result in the tank crew failing to identify a real problem. This might occur when the crew learns the same test is failing in other vehicles. While it may be invalid in some vehicles, it might indeed be valid in others.

Common Problem. If the same test is failing across multiple units and the test is not bad, then a common problem exists and needs to be addressed. The bad hardware/software needs to be resolved as soon as possible.

Number of Failed LRUs. If only a few LRU failures are reported, the problem may not get resolved. When there are large numbers of failures for the same test, the reason behind the failures needs to be quickly determined and resolved. Overriding failures can mask the magnitude of the problem. Resources may be directed toward other more widely reported problems instead of the larger 'hidden' one.

Undefined Actual Operational Readiness. If the Tank Commander (TC) overrides the test, or those above the TC in the chain of command override the failure report, a vehicle may be rated as combat ready when a potentially serious problem is aboard. The Tank-Automotive Armament Command (TACOM) Commanding General, MG N. Ross Thompson III gave a briefing discussing the state of readiness in vehicles entering Iraq to the Chief, Logistics, Coalition Forces Land Component Command, MG Claude V. Christianson. During this briefing, MG Thompson estimated that "FORSCOM IG unit maintenance brief findings state reported readiness rates exceeding 90% while actual readiness [was] at less than 50%"(MG Thompson 2003).

Logistics. The supply of spares on hand might need to be increased, but problems aren't being identified in the supply chain. When there are multiple vehicles requiring a replacement LRU and the problem is not recognized because the overridden failures are not reported, there won't be enough spares to satisfy this need.

Additional Failures. Continuously overlooking a failure may impact or mask other problems developing in the same piece of hardware. This may cause the developing problem to be overlooked, thus creating a potential hazardous situation and jeopardizing the actual readiness of the unit.

Trend Analysis. Failed LRUs should undergo trend analysis to determine if failures are occurring after a period of time or usage, or if multiple problems are developing in the same area. Not reporting failures prevents this type of analysis. Trend analysis for software issues can indicate whether the software is too complicated or has had too many modifications applied. This information is important to the group maintaining the software and is used for decisions such as whether the software should be repaired or needs to be replaced.

B. PROPOSED SOLUTION

Commanders will continue to have the capability to override test results during combat situations. This capability will continue to be available up the chain of command. However, failures cannot be overlooked; the ramifications are too serious. A simple solution is to modify the test software so that, when *not* in combat mode, each failure requires a comment. Test results for *all* failures, with accompanied comments, will be stored in a vehicle database. At a later time, while undergoing routine preventive maintenance, test results will be included as part of the hardware readiness report submitted by the maintenance facility. They will also be merged into a Master Fault database residing at each level of command above the vehicle, along with any comments or explanations for overriding vehicle(s) readiness status by the higher command.

This information will be used to perform trend analysis at the vehicle's major command and provide commanders with an accurate understanding of the actual readiness of the vehicles under that command.

C. THESIS ORGANIZATION

This chapter gives a brief description of the problem, providing an accurate picture of the operational readiness of vehicles within a major command, and then offers a solution to this problem. Chapter II presents an analysis of the current Unit Readiness Index tracking process. It explains the tests that are used to determine the readiness of a vehicle and gives examples of reports currently generated from this data. The chapter also performs a high-level use case analysis of the proposed enhancement offered in Chapter I.

Chapter III contains elements of a design for a Master Fault Database, which is part of the proposed problem resolution. The design includes Object diagram; sample database layouts; and closes with several sample reports generated using the database. Chapter IV is the thesis' conclusion. It discusses the value added by the proposed enhancement as well as challenges and opportunities associated with the implementation of this solution.

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II. ANALYSIS OF THE UNIT READINESS INDEX TRACKING PROCESS

A. UNIT READINESS INDEX

The Army currently uses a Unit Readiness Index to determine the state of readiness of units of all sizes. Units may vary from a squad of tanks, for example, all the way to a brigade or higher. Information is extracted from the "Army's unit status report (USR), which is a part of the Global Status of Resources and Training System (GSORTS). GSORTS is an internal management tool for use by the Chairman, Joint Chiefs of Staff (CJCS), the Joint Staff, the Services, the unified commands, and the combat support agencies. GSORTS is the single automated reporting system within the Department of Defense that is the central registry of all operational units of the U.S. Armed Forces and certain foreign organizations. As a unit readiness system, GSORTS indicates the level of selected resources and training required to undertake the mission(s) for which a unit was organized or designed. GSORTS provides this information on measured units at a specific point in time." (U.S. Army 2001)

Three resource areas are examined: personnel, including the personnel's training status, equipment-on-hand, and equipment serviceability, using the criteria provided in regulation 220-1. Each unit commander also determines an overall unit status level by considering the status of the unit's measured resource areas and training status and by applying his professional judgment. This information, including remarks submitted to clarify category levels, is gathered together to create a Mission Accomplishment Estimate (MAE). The MAE is the reporting unit commander's subjective assessment of the unit's ability to execute that portion of the wartime mission that it would be expected to perform if alerted/committed within 72 hours of the "as-of" date of the report. The commander expresses this estimate in terms of the percentage of the wartime mission that the unit could accomplish if it were alerted/committed.

The information is gathered via the Personal Computer/Army Status of Resources and Training System (PC/ASORTS), whenever possible, or is submitted via DA Form 2715. Reports are submitted as of the 15th day of each month and must be received within 96 hours of the due date.

The “National Security and Military Strategies require the Army to provide forces capable of world-wide operations across the full spectrum of conflict, from small peacetime engagements to major regional wars. In order to meet these readiness challenges, we must resource the Army with quality people, lead by competent and confident leaders, and armed with reliable, modern equipment.” (DAVID L GRANGE, MG 1997) Thus, we need to know the following:

- How can we determine what our state of readiness actually is?
- If the state is too low, what specified minimal level should that state be raised to?
- What will it take to raise it to that level?
- How accurate is this assessment?

Units determine and report in the Unit Status Report (USR) an equipment serviceability (ES) level (R-level) (See Table 1, extracted from Table 6-1 in AR220-1.). The unit’s R-level indicates how well the unit is maintaining its on-hand equipment.

Level	Equipment other than aircraft	Aircraft
1	100–90%	100–75%
2	89–70%	74–60%
3	69–60%	59–50%
4	Less than 60%	Less than 50%

Table 1 Level for percentage of equipment fully mission capable

Once a measurement of the overall state of equipment is determined, decisions can be made as to what actions should be taken to raise a substandard level of readiness to an acceptable level. For example, a cost tradeoff analysis may be made to determine if the hardware should be improved, if software modifications should be made, or if some combination of the two must be performed.

There are three levels of testing performed on the M1A2. These are described in Table 2 and are extracted from the Fault Management volume of the M1A2 System/Segment Design Document (GDLS S/SDD 2003).

Self -Test (ST)	Self-Test is the first level of embedded diagnostics within the M1A2 tank. ST reports faults to the crew during all modes of operation. Self-Test data runs in the background of each LRU. ST runs upon power-up and performs a health check on the system without affecting tank functions.
Built-In-Test (BIT)	Built-In-Test is the second level of embedded diagnostics. BIT is an intrusive test of the system health status.
Fault-Isolation-Test (FIT)	Fault Isolation Test is the third level of embedded diagnostics. FIT utilizes the results from Self-Test and Built-In-Test to reduce ambiguity groups within the system. The corresponding ST and BIT results are incorporated into variables. These variables make up several hundred Boolean equations to isolate faulty units and generate troubleshooting procedure (TP) numbers.

Table 2 Levels of Software Testing

1. Self-Test

Self-Test (ST) runs continuously in all modes, and is the first level of diagnostics to detect a failure. Upon detection of a failure, a NOGO message is displayed on the Commander’s Integrated Display (CID), with a backup copy of the message displayed on the Gunner’s Control and Display Panel (GCDP). The message identifies the LRU containing the failure, i.e., if a failure is detected in the DID LRU, the NOGO displayed is for that LRU.

2. Built-In-Test

Once ST detects a failure, the tank crew is expected to perform further diagnostic testing using Built-in Test. Figure 4 is a screen shot showing the status of the LRUs in the M1A2, following BIT.

This testing can only be performed while in Diagnostics mode – if the vehicle is in Combat or some other mode, testing must be delayed (due to the intrusive level of the BIT testing.) Once in Diagnostics mode, BIT is executed to confirm the failure. BIT is more stringent; for an LRU, according to paragraph 1.1.3 of the S/SDD (GDLS S/SDD 2003);

> "The BIT diagnostics augmented by Manual Test Procedure (MTP), shall meet the following requirements:
>
> a. Ninety-five percent probability of detecting all on-board system-level faults.
>
> b. Zero ambiguity in fault isolation of a system.
>
> c. Ninety-percent probabilities of fault isolating to a LRU or Line Replaceable Module (LRM).
>
> d. Less than TEN PERCENT BIT false alarm rate.
>
> e. BIT failure shall not degrade performance of the prime system (i.e., BIT failure is transparent to systems operation).
>
> f. BIT shall have self-test capability."

When ST or BIT detects fault conditions that cannot be resolved or explained, the problem, including a description of the extent of the failure and a recommended severity level, is submitted to organizational maintenance.

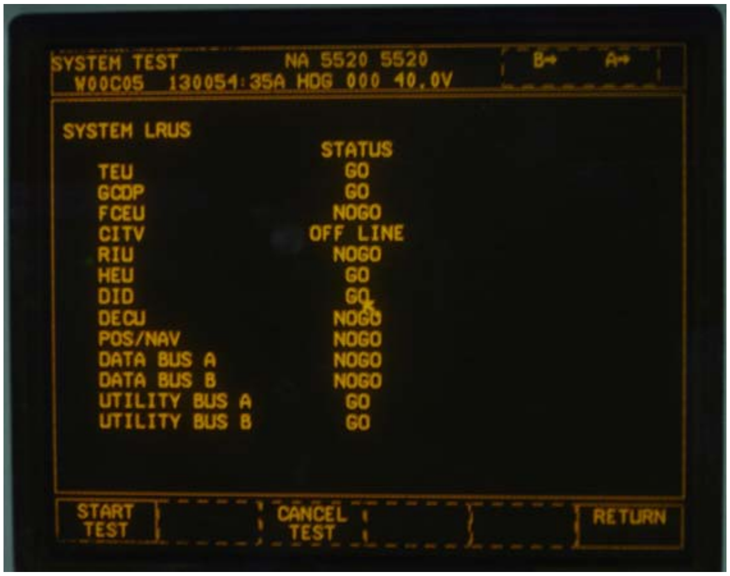

Figure 4 BIT Vehicle Test Results

3. Fault-Isolation-Test

After verifying the problem is reproducible (by re-running BIT), maintenance personnel will run the Fault-Isolation-Test using a Direct Support Electrical System Test Set (DSESTS), shown on the left in Figure 5 below.

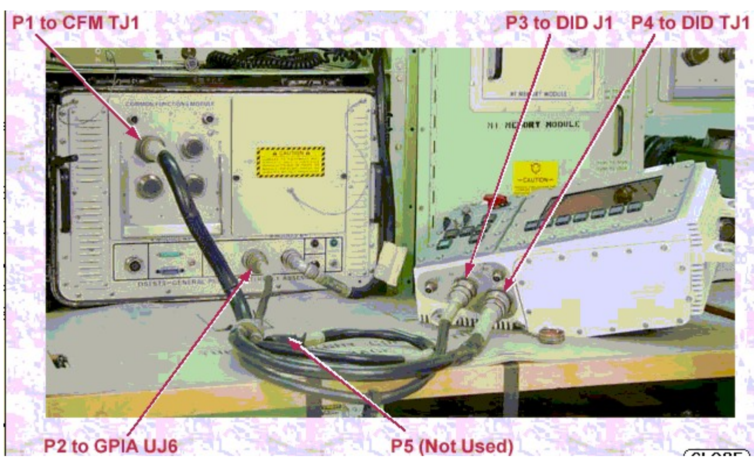

Figure 5 DSESTS, connected to a DID

If FIT also fails, the maintenance unit will replace the faulty Line Replaceable Unit (LRU) hardware. When the maintenance unit determines the problem exists in multiple LRUs they will declare that an LRU ambiguity group exists. (If the failure cannot be isolated using these tests, the maintenance personnel will perform manual testing to try to identify the problem.)

Unit maintenance will perform further testing using the Intermediate Forward Test Equipment/Commercial Equivalent Equipment (IFTE/CEE). An LRU typically consists of one or more Shop-Replaceable Units (SRUs). An example of an SRU would be a circuit board contained in an LRU (See Figure 6, below) or the 1553B cable connecting the LRU to the network. The IFTE/CEE tests to the sub-SRU level; i.e., it examines the components on a circuit board. Figure 7 lists actual LRUs and embedded electronic module SRUs for an M1A2.

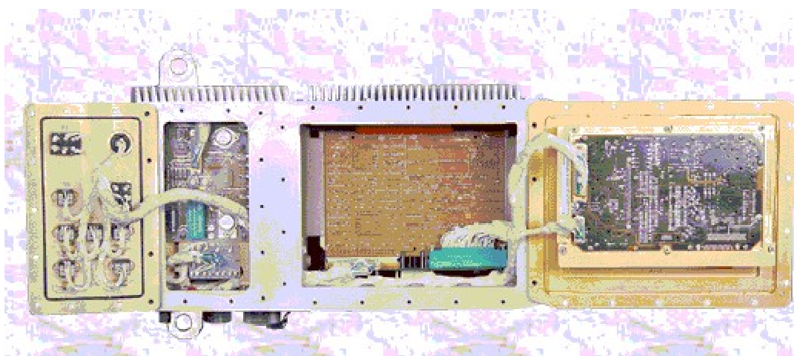

Figure 6 Driver's Integrated Display - Internal View

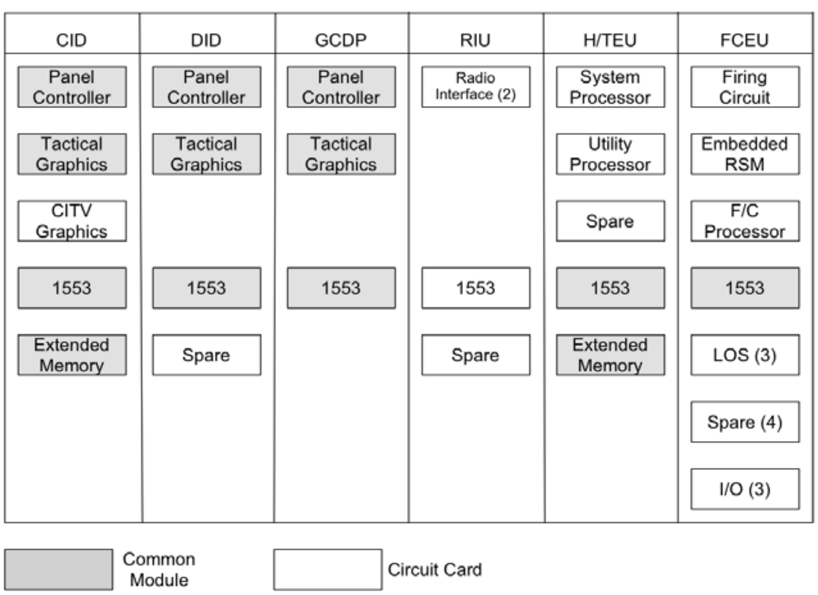

Figure 7 M1A2 LRUs and Electronic Module SRUs

When a failure occurs and a FIT warning is displayed, the Tank Commander or Maintenance crewmember can display the corresponding troubleshooting procedure (TP) number. Figure 8 is a screen shot, showing TP #s generated during FIT. Each TP number is unique and uses the results from Self-Test and Built-In-Test to reduce ambiguity groups within the system. The corresponding ST and BIT results are incorporated into variables. These variables make up several hundred Boolean equations to isolate faulty units and generate troubleshooting procedure (TP) numbers. For example,

"TP# 302 will be generated if the [remote power control] RPC on the [Hull Power Distribution Unit] HPDU that supplies power to DID is TRIPPED or NO-LOAD. At the same time, 1553 data bus communication must be valid to DID. TP# 302 is represented by the following equation.

1v = (AM_HPDU_RPC_8_TRIP_DID or AN_HPDU_RPC_8_NO_LOAD_DID) and IU_DATA_BUS_A_DID and IV_DATA_BUS_B_DID"

A detailed set of formulae used for determining these troubleshooting procedures are contained in the M1A2 System/Segment Design Document. (GDLS S/SDD 2003)

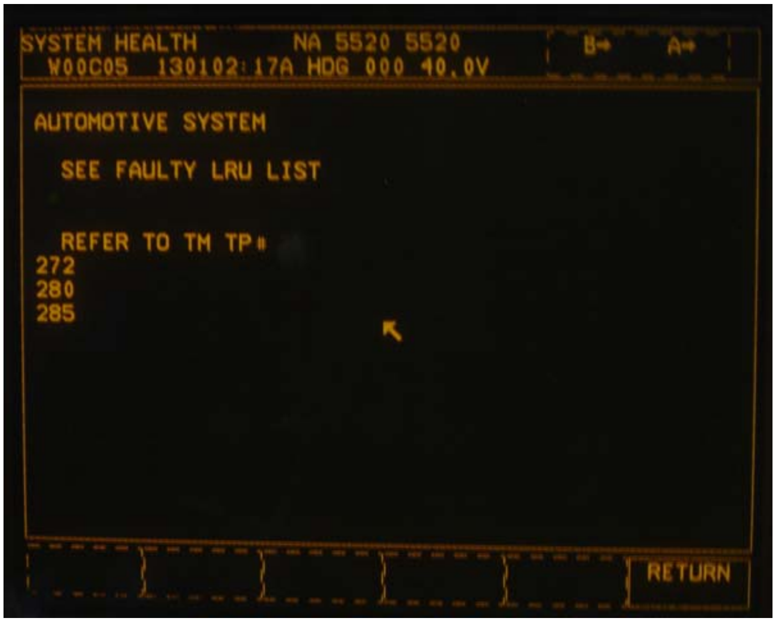

Figure 8 Sample FIT TP #s

B. EXISTING REPORTS

Data is generated at the unit level and gathered by the Army Material Status System where it is stored in the Readiness Integrated Data Base (RIDB). The RIDB is used for analysis of readiness data generated from unit status, aircraft, missile, and ground equipment reporting. Two reports are issued using data within the RIDB: Operational Readiness Summary Reports, which show the Operational Readiness status within the Major Command at the date the report is generated, and the Equipment Downtime Analyzer Report, which shows more detailed information for the date the report is generated. Both reports only go to a vehicle level of detail. Failure information on LRUs, while reported by the Unit, is not covered by either of the two reports.

1. Operational Readiness Summary Reports

Figure 9 shows four actual examples of the summary reports of the operational readiness for one of the fielded M1A2 Divisions. They explain why the Operational Readiness goal of 90% wasn’t met, and what actions are being taken to resolve it. Each report reviews the Fully Mission Capable (FMC) Index for the reporting period. There are several issues to highlight:

The FMC Index is an average value for the appropriate monthly period. It does *not* address figures for any specific day. The daily Index may be much higher (or lower) than the monthly value. Moreover, units being deployed are not included in the reports and the reports consistently recommend the same near-term fixes.

Monthly Backup Information
M1A2 Abrams Tank
FMC as of 15 Nov 03 – 86.1%

REASONS WHY THE M1A2 DID NOT MEET GOAL:

1. The RIDB data for the period ending 15 Nov 03 shows an M1A2 FMC of 86.1% with 385 vehicles reported. The density at 1CAV is short 159 vehicles from last report period. The major units that failed the DA goal for M1A2 are listed in the matrix below:

UNIT	QTY	FMC	NMCS	NMCM
3 ACR	124	82%	14%	4%
4 ID	124	81%	16%	3%

2. 3ACR, SWA: The 3rd ACR readiness has improved by 5% FMC from 77% to 82%. The 3ACR continues to see high OPTEMPO during deployment to OIF. Suspension parts continue to be impacted by the terrain in theater. Parts are flowing into theater, causing an improvement in readiness.

3. 4th Infantry Division, SWA: The readiness of the Abrams in the 4th ID increased by 5% FMC from 76% to 81% FMC. The 4th ID is deployed to OIF and is seeing high OPTEMPO. Suspension parts continue to be impacted by the terrain in theater. Parts are flowing into theater, causing an improvement in readiness.

READINESS ENHANCEMENT ACTIONS:

Near - Term Fixes:
- Road Wheel and Arm assemblies NMCS backorders filled in Dec03.
- Intense management and focused distribution of critical supply items.
- TAP available to fill/fix Abrams unique parts in SWA.
- Disassembly programs in place to obtain critical parts.

Extended Fixes:
- Improve distribution system in theater.
- Ramped up deliveries on critical assemblies.
- RESET vehicles to 10/20 standards; program unfunded.

Monthly Backup Information
M1A2 Abrams Tank
FMC as of 15 Feb 04 – 80.4%

REASONS WHY THE M1A2 DID NOT MEET GOAL:

1. The RIDB data for the period ending 15 Feb 04 shows an M1A2 FMC of 80.4% with only 172 vehicles reported. Last month 445 vehicles were reported. The 1CAV did not report during deployment to SWA, and 3ACR did not report during Redeploy. The 4th ID and Ft Knox are the only units that reported M1A2s for Feb04:

UNIT	QTY	FMC	NMCS	NMCM
Ft. Knox	50	72%	12%	16%
4 ID	122	84%	10%	6%

2. Ft. Knox: The readiness at Ft. Knox decreased from 86% to 72%FMC. Ft. Knox is a TRADOC unit with a low Force Activity Designation (FAD). Requirements for Deploying/Redeploying units receive higher priority. High OPTEMPO, fleet age, and personnel availability are all affecting the unit's ability to maintain readiness.

3. 4th Infantry Division, redeploying: The readiness of the Abrams in the 4th ID only dropped slightly from 85% to 84%FMC. The 4ID is in the process of redeployment. The vehicles are being prepared for transportation back to home station or depot for repair. The requisitions for 4ID in-theater are in the process of being cancelled.

READINESS ENHANCEMENT ACTIONS:

Near - Term Fixes:
- Intense Management of NMCS requistions.
- Disassembly programs in place to obtain critical parts.

Extended Fixes:
- Ramped up deliveries on critical assemblies.
- RESET vehicles to 10/20 standards.

Monthly Backup Information
M1A2 Abrams Tank
FMC as of 15 Apr 04 – 86.8%

REASONS WHY THE M1A2 DID NOT MEET GOAL:

1. The RIDB data for the period ending 15 Apr 04 shows an M1A2 FMC of 86.8% with only 174 vehicles reported. The 3ACR and Ft Knox are the only units that reported M1A2s for Apr 04. The following unit missed the DA goal:

UNIT	QTY	FMC	NMCS	NMCM
3ACR	123	85%	8%	7%

2. 3ACR: The 3ACR has just finished its tour in OIF, and is currently redeployed. The vehicles are currently in transit from overseas. No systemic issues identified.

READINESS ENHANCEMENT ACTIONS:

Near - Term Fixes:
- Intense Management of NMCS requisitions.
- Disassembly programs in place to obtain critical parts.

Extended Fixes:
- Ramped up deliveries on critical assemblies.
- RESET vehicles to 10/20 standards.

Monthly Backup Information
M1A2 Abrams Tank
FMC as of 15 Jun 04 – 88.5%

REASONS WHY THE M1A2 DID NOT MEET GOAL:

1. The RIDB data for the period ending 15 Jun 04 shows an M1A2 FMC of 88.5% with only 268 vehicles reported. This is an increase from the May04 FMC of 85.1%. The following units missed the DA goal:

UNIT	QTY	FMC	NMCS	NMCM
3ACR	127	81%	7%	12%
Ft. Knox	52	86%	6%	8%

2. 3ACR: The 3ACR has just finished its tour in OIF, and is currently redeployed. The vehicles are currently in transit from overseas. The majority of downtime is attributed to maintenance (12%NMCM). No systemic supply issues identified.

3. Ft. Knox, TRADOC: The M1A2s at Ft Knox showed a slight decrease in readiness from 87% to 86% FMC. Ft. Knox is a TRADOC post, and continues to have high OPTEMPO due to preparing units for deployment. In addition, due to the FAD (Force Activity Designator) code this unit cannot order items higher than a "03" priority. Unit Maintenance Activity (UMA) is behind on services causing delays in repairing vehicles.

READINESS ENHANCEMENT ACTIONS:

Near - Term Fixes:
- Intense Management of NMCS requisitions.
- Disassembly programs in place to obtain critical parts.

Extended Fixes:
- Ramped up deliveries on critical assemblies.
- RESET vehicles to 10/20 standards.

Figure 9 RIDB November 03, February 04, April 04 and June 04 Summaries

2. The Equipment Downtime Analyzer Reports

The Equipment Downtime Analyzer (EDA) Report "provides insight through comparison of different organizations and end item fleets. It can help answer questions such as:

> Is this fleet's readiness problem the result of high repair time, a high failure rate, or both?
>
> Is an organization's long repair time driven by organizational or support level repairs?
>
> How much does parts wait time contribute to repair time?
>
> What parts are contributing the most to lost readiness?
>
> If inventory is improved, what will be the effect on equipment readiness?"(CASCOM)

The EDA report also covers a monthly period, but uses a calendar month timeframe, rather than the URI timeframe of the 16th of one month to the 15th of the next. It provides more detail than the RIDB summary, allowing the user to "drill down" within the report to determine just how long a specific vehicle was considered Non Mission Capable (NMC) and why. However, like the Operational Readiness Summary Report the EDA report only goes to the vehicle level, Figure 10 is a sample top-level report.

The Major Command has the capability of examining logistic reports for spare parts ordered and generating a report of LRUs that are failing within the command. However, occasionally the wrong part is ordered and a second LRU is needed to correct the problem. This means that looking at logistical reports of parts ordered does not necessarily provide an accurate picture of LRU failure trends.

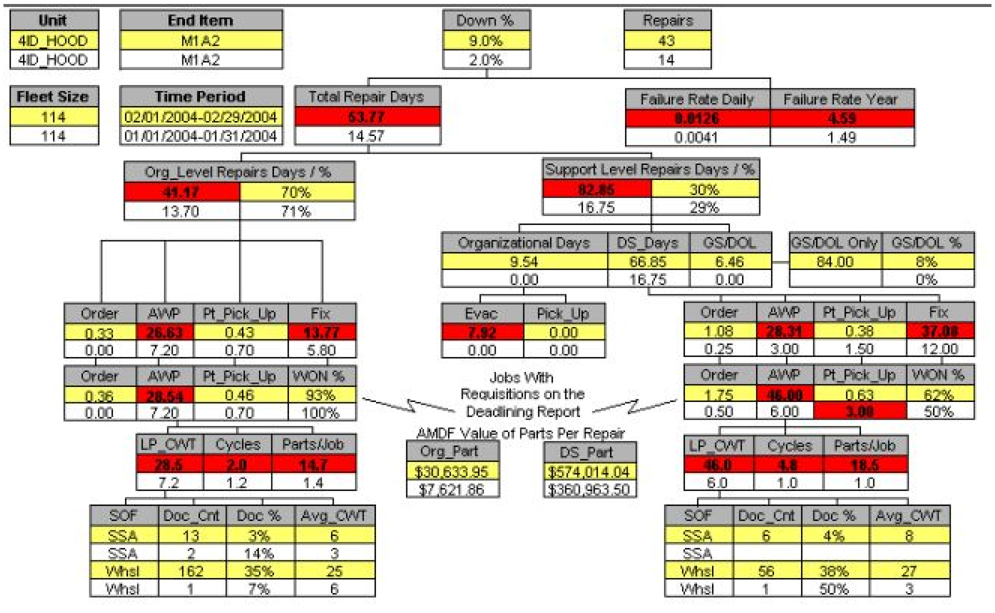

Figure 10   EDA Report for 4ID - 01/04 - 02/04

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III. PROPOSED ENHANCED PROCESS

The GO/NOGO approach is well known, has been in use for a long time, and will continue to be used. The information generated from the reports in Section B of Chapter II above, tracks to the vehicle level. This needs to be enhanced to be more proactive in addressing failures.

A. USE CASE ANALYSIS

Use Cases are valuable because they allow a process to be broken down into an easily understood set of diagrams. Use Case methodology will be used here to explain the proposed process. "A use case has two parts: the use case diagram and the use case itself. The diagram provides an overview of which interactions will be important, and the use case's text details the requirements." (Daryl Kulak and Eamonn Guiney 2002)

Use cases show the interaction between the system and external entities, called Actors. Figure 11 is the system level context diagram for the Master Fault Database. For the proposed process, there is one system called the Master Fault Database, which interacts with several Actors. The Actors are as follows:

- The Vehicle Database, from which the majority of the raw data is extracted.
- Users at the vehicle's maintenance facility who will close out the fault record in the Database once the LRU has been repaired/replaced and the vehicle declared Mission Capable. (This assumes there is only one fault. When multiple faults occur, as each LRU becomes operational within the vehicle, the fault will be considered to be resolved.)
- Users at some level between the vehicle and the Major Command. These actors will be adding additional comments such as why the vehicle's Readiness Report is overridden.
- Users at the Major Command that will be using the raw data to generate reports used in trend analysis and for logistics.

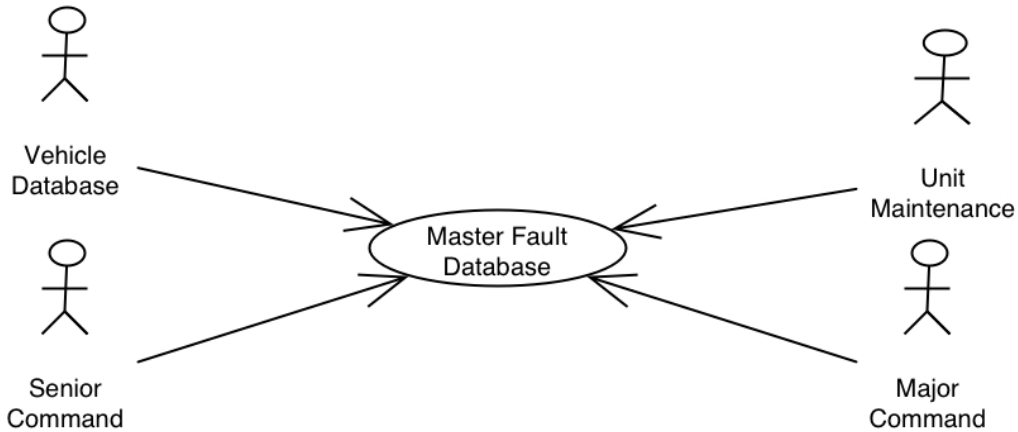

Figure 11 System Level Context Use Case - Master Fault Database

There are four use cases associated with this system. Because the number of actors interfacing with the system is small and straightforward, the use case diagrams are not included. Instead, the use case descriptions, in table format, are provided as stand-alone entities.

1. Fault Data Collection Use Case

This use case describes the process of recognizing a fault and collecting related data. It also describes uploading accumulated data to the Master Fault Database and resetting the Vehicle Database to free up precious space on the vehicle.

Use Case Name: Fault Data Collection
Actors: Tank Crew, Unit Maintenance Crew, Vehicle Database
Summary: When a fault has been detected in a vehicle, related data is collected. During maintenance, after verifying the fault is repeatable, the fault data is transferred to the Master Fault Database and the Vehicle Database is reset.
Basic Course of Events: 1. Vehicle performs self-test and detects a fault. 2. Vehicle notifies Tank Crew of the failure and stores failure information in the Vehicle Database.

3. Tank Crew runs BIT to verify the fault exists. If necessary, Tank Crew adds comments to the Vehicle Database. 4. Vehicle updates the Vehicle Database. 5. Maintenance Crew will re-run BIT. If the fault is repeatable, they will run FIT and, if necessary, add comments to the Vehicle Database. 6. Vehicle will update the Vehicle Database with new comments and add TP # data. 7. Maintenance Crew transfers data from the Vehicle Database to the Master Fault Database. After receiving an acknowledgement from the Master Fault Database, the vehicle will reset the Vehicle Database.
Alternative Paths: N/A
Exception Paths: In step 5, if the problem is non-repeatable, the fault record will be deleted from the Vehicle Database
Trigger: A fault is recognized
Assumptions: The vehicle is not in Combat mode.
Preconditions: Vehicle is running
Postconditions: New records added to the Master Fault Database; Vehicle Database has been reset
Date: 20-Dec-04

Table 3 Fault Data Collection Use Case

2. Override Readiness Index Use Case

This use case describes when a User in the Senior Command, above the Unit level, has overridden the Unit Readiness status of a vehicle. That User must also add a comment to the appropriate record in the Master Fault Database. Note that even though the vehicle is considered Mission Capable, the fault will continue to exist in the Master Fault Database until someone in the Unit Maintenance group corrects the problem. Only then will the fault be closed.

Use Case Name: Override Readiness Index
Actors: Senior Command Member
Summary: When a member of the Senior Command wants to override the vehicle's Operational Readiness status, information identifying the User, together with a comment explaining the action taken, must be added to the Master Fault Database.
Basic Course of Events: 1. The User logs on to the Master Fault Database. 2. The system displays a list of options to the User. 3. The User requests access to a vehicle's record. 4. The system displays the appropriate record and prompts for additional information. 5. The User enters requested information, including a comment on the change in Operational Readiness status. 6. The System updates the record within the Master Fault Database. 7. The User logs out of the database.
Alternative Paths: In step 7, if the user wants to modify another vehicle's record, steps 3 through 6 are repeated.
Exception Paths: In step 3, if the User enters an invalid vehicle identifier, the System displays an error message and re-prompts for the vehicle identification. The User may also go directly to step 7.
Trigger: The User requests to update a record in the Master Fault Database
Assumptions: Someone in the vehicle's chain of command has decided the vehicle is Mission Capable
Preconditions: A Unit Readiness Report has been received indication the vehicle is NMC.
Postconditions:

1. The vehicle is considered Mission Capable. 2. The Master Fault Database continues to show a fault.
Date: 20-Dec-04

Table 4 Override Readiness Index Use Case

3. Report Generator Use Case

This use case describes when a User in the Major Command requests a new report. Reports are usually run on a scheduled basis but may also be run on an exception basis. Moreover, reports are typically run at the Major Command but may be run by anyone within the chain of command. E.g., someone in Unit Maintenance might request a report if there is a concern about similar problems with other vehicles.

Use Case Name: Report Generator
Actors: Authorized User within the vehicles chain of command (up to the Major Command level)
Summary: A User requests a report be generated. The report is generated using data from the Master Fault Database
Basic Course of Events: 1. User logs onto the Master Fault Database and requests a report. 2. System displays available reports for that specific User 3. User chooses a report. 4. System processes the data and generates the report. 5. User logs out of the database
Alternative Paths: In step 5, when additional reports are requested, steps 2 through 4 are repeated.
Exception Paths: In step 3, if the User is not authorized to request a specific report, step 2

is repeated. The User may choose to go to step 5 if desired.
Trigger: N/A
Assumptions: User has access to the desired reports.
Preconditions: User has logged onto the Master Fault Database
Postconditions: Desired reports are generated
Date: 20-Dec-04

Table 5 Report Generator Use Case

4. Close Vehicle Fault Use Case

This use case describes the steps taken when a member of the vehicle's unit maintenance group closes a fault. Note that only someone from the Unit Maintenance activity has authority to close a record. That will prevent accidental closings, which in turn would cause invalid trend analysis. A fault may be closed without changing the status of the vehicle's Operation Readiness. This may occur if there is more than one fault for an LRU, or if the vehicle is considered NMC because multiple LRUs have failed. The vehicle will be considered Mission Capable when all faults have been closed for that vehicle.

Use Case Name: Close Vehicle Fault
Actors: Unit Maintenance personnel
Summary: Someone from Unit Maintenance requests a vehicle's fault record in the Master Fault Database be changed to closed for a specified fault
Basic Course of Events: 1. A User logs on to the Master Fault Database. 2. The system displays a list of options. 3. The User chooses to close a fault and enters the appropriate information.

4. The system updates the Master Fault Database. 5. The User logs out of the database.
Alternative Paths: In step 5, if the User wants to close another fault record, steps 3 and 4 are repeated.
Exception Paths: If the User is not authorized to close a fault record, the system will display an error message and go to step 5.
Trigger: N/A
Assumptions: The User is an authorized member of the Unit Maintenance crew.
Preconditions: A fault has been corrected in a vehicle.
Postconditions: The Master Fault Database has closed the fault record.
Date: 20-Dec-04

Table 6 Close Vehicle Fault Use Case

B. SEQUENCE DIAGRAM

Figure 12 is a sequence diagram, showing the interaction between the different users and the database. Initially, fault data captured in a Vehicle Database will be transferred to the Master Fault Database. Once a new record has been created, an acknowledgement will be sent back to the Vehicle Database, which will then be reset. There is limited space available in the vehicle; as soon as possible, old data must be cleared out. At the same time, a Unit Readiness Report will be submitted up the chain of command. At some level above the unit, a user in a Senior Command may decide to add additional information into the Master Fault Database, such as justification for overriding the NMC status of a vehicle.

Periodically, users at the Major Command level will run reports to perform trend analysis and to view a more accurate Operational Readiness within the command.

Finally, once unit maintenance personnel have resolved the fault (i.e., replaced the hardware, downloaded a new version of software, etc.), the fault record will be closed within the Master Fault Database.

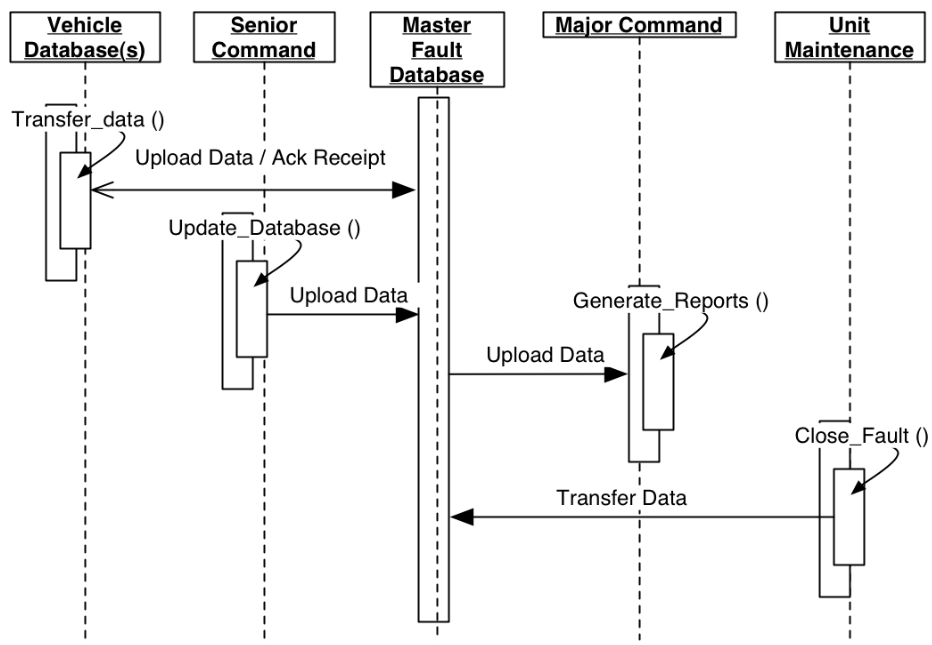

Figure 12 Master Fault Database Sequence Diagram

C. THE PROPOSED REPORTING PROCESS

New reports, tracking failures to the LRU level and including the TP #s to further isolate the faults, will be added to the current process. Several steps are needed to implement this enhancement on the M1A2 Abrams. A similar approach would be used for other vehicles, modifying the terminology for the Commander's display.

- A vehicle database will be added to the CID LRU. This database will be used for collecting the Tank Commander's comments. It will also gather relevant information for each of the warnings:
    - Applicable LRU data (hardware serial number; software version)
    - Troubleshooting Procedure numbers (TP#s), used to describe which test procedure failed.

- A check will be performed to eliminate duplicate reports. I.e., when BIT and/or FIT are run after ST generates a warning, only one set of data will be required. Also, if the vehicle is on a multi-day exercise, and the TC decides to continue use of the vehicle until the exercise is complete, the same error might be identified over several days. Only one occurrence of the fault should be captured.
- The process for undergoing routine scheduled maintenance will be modified to include gathering fault-generated data stored in the Vehicle Database.
- Data from Vehicle Databases will be added to a Master Fault database. This master database will be owned and maintained at the Major Command, but will be accessible throughout the chain of command.
- Management, up the chain of command, will incorporate any override or other comments into the Master Fault database.
- Upon request, the major command will generate trend analysis reports. The results of this analysis will be forwarded to the appropriate logistics group for hardware support and to the Software Life Cycle Maintenance group for software and test support.
- Units below the Major Command can also generate specific reports. These reports will be useful when a subordinate unit wants to perform their own trend analysis.
- For all of the above, proper training will be developed and implemented.

Several steps must be taken to incorporate these databases.

- A new Vehicle Database will be added to the vehicle's existing software. The physical location of this database will take into consideration available space for the new code. Some LRUs have more space available than others. If needed, data entered will be passed to the database via the 1553 data bus that connects all the major LRUs.

- Screens will be developed within the vehicle to allow data entry. The screens will be added to the CID with backup capability in the GCDP.

- When a fault occurs, the TC will enter pertinent data into the Vehicle Database. This will include whether the LRU problem is addressed at that time or if the problem is overridden.

- A Master Fault Database for all of the vehicles will be accessible by the local maintenance facility. The data in the Vehicle Database for each vehicle will be transferred to the Master Fault Database. Data from other Vehicle Databases will also be added as the Master Fault Database grows.

- Faults are identified on a DA Form 2404, using an "X" to identify the problem. When the DA Form 2404 has a fault overridden at a level higher than the vehicle, a Circle-X is used. As this occurs, the user must enter a comment into the Master Fault database as to why the X was overridden.

- Data from the Master Fault database will be accessible by the Program Manager's office for trend analysis. Assuming a failure trend is identified, funding will be requested to address the invalid software/hardware/test software.

- Also dependent upon the trend analysis, an adjustment will be made for the number of spares requested/needed.

IV. MASTER FAULT DATABASE DESIGN

A. OBJECT DIAGRAM

According to Martin Fowler's book on UML, "An object diagram is a snapshot of the objects in a system at a point in time." (Martin Fowler and Kendall Scott, 2000). The object diagram for this system (shown in Figure 13) will consist of the objects described in Table 7. This table also shows the relationships (1 to many, many to many, or many to 1) between the two objects.

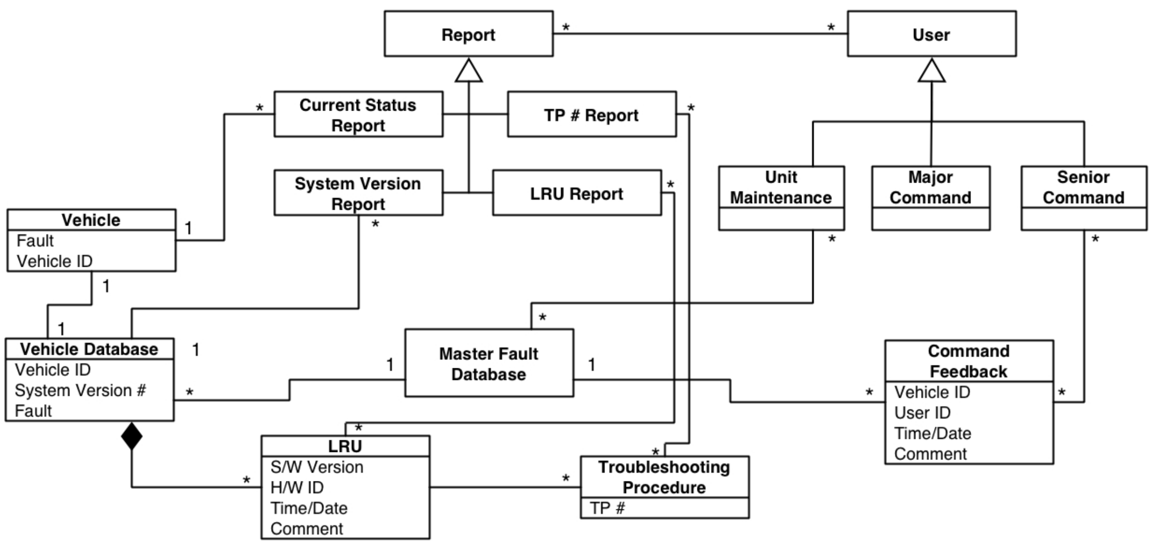

Figure 13 Master Fault Database Object Diagram

Object	Relationship	Object	Description
Report	generalization		Consists of four (sample report) objects: Current Status Report; System Version Report; TP # Report; and LRU Report.
User	generalization		Consists of three objects: Unit Maintenance; Major Command; and Senior Command.

Report	*-*	User	One or more users can generate one or more reports.
Vehicle	1-*	Current Status Report	One or more vehicles will be described in the Current Status report.
Vehicle	1-1	Vehicle Database	Data for each (unique) fault is collected in that vehicle's Vehicle Database.
Vehicle Database	1-*	LRU	The Vehicle Database contains an aggregate of data for the faulty LRU.
LRU	1-*	Trouble-shooting Procedure	Each LRU contains an aggregate of one or more TP #s.
Vehicle Database	1-*	System Version Report	The System Version Number for each vehicle will be used in the System Version report.
LRU	*-*	LRU Report	Data from many LRUs will be used in the LRU Report.
Troubleshooting Procedure	*-*	TP # Report	Data from many TP #s will be used in the TP # Report.
Vehicle Database	*-1	Master Fault Database	One or more vehicles will provide data to the Master Fault Database.
Senior Command	*-*	Command Feedback	One or more members of the Senior Command provide input to the Command Feedback object.

Command Feedback	*-1	Master Fault Database	One or more Command Feedback sets provide updated data to the Master Fault Database for each fault in the database.
Unit Maintenance	*-*	Master Fault Database	One or more Unit Maintenance personnel close one or more faults when the faults are resolved.

Table 7 Object Relationships

B. DATABASE DESIGN

1. Database Contents

The Master Fault Database will contain information collected from the Vehicle Databases throughout the command as well as information entered by the various levels between the Major Command and the Vehicle level. Table 8 identifies the data, where it is derived from, and why it is included in the database.

Data	Source	Comment
Vehicle System Software Version	From the CID LRU (Vehicle Database)	Used for trend analysis
LRU ID	From in the CID LRU (Vehicle Database)	Used for trend analysis
TP #	From the CID LRU (Vehicle Database)	Used for trend analysis
Vehicle ID	Entered by the TC (Vehicle Database)	Unique value, used as the Primary Key.
Date/Time	Entered by the TC (Vehicle Database)	Used to determine how long the vehicle was NMC.
Vehicle Operational	Entered by the TC	Used for trend analysis, and to

Data	Source	Comment
Readiness Index Override?	(Vehicle Database)	determine actual operational readiness.
Reason for Override	Entered by the TC (Vehicle Database)	Used for trend analysis, and to determine actual operational readiness.
Additional comments	Entered by the TC (Vehicle Database)	Used by maintenance, for reasons for failures, and by logistics personnel when ordering spares.
Vehicle Operational Readiness Index Override	Senior Command personnel	Corresponds to a circle-X. Used to determine actual operational readiness
Reason for Override	Senior Command personnel	Used to determine actual operational readiness
Date/Time of Override	Senior Command personnel	Used to determine actual operational readiness
Overriding Authority Identification	Senior Command personnel	Used to determine actual operational readiness
Additional Comments	Senior Command personnel	Used to determine actual operational readiness

Table 8 Master Fault Database Contents

2. Sample Database Layout

Records within the Master Fault Database consist of fields containing data transferred from the individual Vehicle Databases and additional fields containing data from senior commands over the reporting vehicles. In keeping with best practices for database design, the data will be divided into several tables to minimize the possibility of data corruption, keep the database more manageable, and speed processing.

The primary key for each table will be the vehicle ID. Data for a fault will initially be transferred from the applicable vehicle. Additional information may be added by commands above the vehicle level in the chain of command. Maintenance personnel may indicate the fault has been corrected and, depending upon if other faults exist, whether the vehicle is now Fully Mission Capable.

Figure 14 is the Entity Relationship Diagram for the Master Fault Database. There may be one or more failures occurring within a vehicle, so the diagram shows multiple failures submitted to the Master Fault Database. It also shows personnel in the chain of command above the reporting unit may update information on each fault one or more times. I.e., information may be submitted by someone at the Company level, and also by someone at the Battalion level.

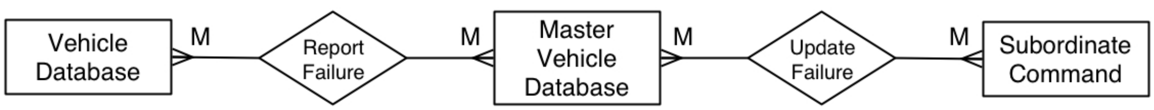

Figure 14 Entity Relationship - Master Fault Database

There are two tables containing data for the Master Fault Database, as described below. Each field of both Table 9 and Table 10 identify the database Primary Key, Field name, type, size, whether it is a required field, and a comment field to explain where the data is derived.

a) Vehicle Data Table

Table 9 contains data extracted from the Vehicle Database. It allows for up to six Troubleshooting Procedure numbers. Each failure within a vehicle will have its own record within the database which will allow individual faults to be closed while still allowing the vehicle to be classified NMC due to any other outstanding fault records. This will also allow a more accurate trend analysis to be performed on individual faults, rather than just on vehicles.

Key	Field	Type	Size	Req'd Field	Comments
P	Vehicle ID	A/N	20 Chars	Y	Captured from the CID LRU Key types are Primary, Secondary, Foreign
	System Version	A/N	10 Chars	Y	Captured from the CID LRU
	LRU	A/N	7 Chars	Y	Captured from the CID LRU
	LRU S/W Vers.	A/N	7 Chars	Y	Captured from the LRU
	LRU H/W Ser. #	A/N	7 Chars	Y	Entered by User (Tank Crew, Maintenance personnel)
	TP #	N	5 Chars	Y	Captured from the CID LRU
	TP #	N	5 Chars	Y	Captured from the CID LRU
	TP #	N	5 Chars	Y	Captured from the CID LRU
	TP #	N	5 Chars	Y	Captured from the CID LRU
	TP #	N	5 Chars	Y	Captured from the CID LRU
	TP #	N	5 Chars	Y	Captured from the CID LRU
	Date/Time	A/N	20 Chars	Y	Entered by User
	Comment	A/N	240 Chars	Y	Entered by User

Table 9 Vehicle Data - Master Fault Database

b) Change in Status Table

Table 10 will contain data entered by members of commands senior to the faulted vehicle. Data may be entered when overriding a circle-x or just in general to explain a failure. It may also be submitted to assist the Major Command when generating a trend analysis report.

Key	Field	Type	Size	Req'd Field	Comments
P	Vehicle_ID	A/N	20 Chars	Y	Captured from the Vehicle's Form 2404
	LRU	A/N	7 Chars	Y	Captured from the Vehicle's Form 2404
	User_Name	A/N	20 Chars	Y	Entered by User
	Unit_ID	A/N	20 Chars	Y	Entered by User. Name of user's Unit
	ChangeStatus	A/M	5 Chars	O	Entered by User
	Date/Time	A/N	20 Chars	Y	Entered by User
	Comment	A/N	240 Chars	Y	Entered by User

Table 10 Change in Status - Master Fault Database

3. Sample Database Reports

Some of the reports that can be generated from this database are:

Current Status of Fielded Vehicles – indicates the status of fielded vehicles within a specified command. By varying the report date, the command can determine trends. It also shows a more accurate Operational Readiness Status.

Failure Analysis By LRU – indicates if there is a fundamental problem emerging for a specified LRU. It will also help ensure the proper numbers of spares are ordered.

Failure Analysis by Troubleshooting Procedures – this report will isolate failures by software or hardware categories. It should be used in conjunction with the Failure Analysis by LRU report when ordering spares. For example, if there are hardware issues, then replacements are needed. But if the TP #s indicate the issues are software related, then updated software should be developed/installed.

Failure Analysis by System Versions – this will identify if issues are being introduced or resolved by different versions of system releases. This report should be used in conjunction with the other failure analysis reports. Failures introduced by new versions of hardware or of software need to be analyzed as a whole rather than individually.

For the following sample reports, the Fourth Infantry Division is (arbitrarily) used. The reports are as follows:

a) Current Status of Fielded Vehicles

This sample report (Figure 15) examines vehicles assigned to the 4th ID. For each NMC vehicle, the vehicle identification is displayed together with the date the vehicle became NMC. This information allows the Major Command to take action as appropriate: move vehicles from one unit to another, check on status of spares, determine if command assistance is required to resolve delays, etc.

Current Status of Fielded Vehicles

Command: 4ID — Date: XX/XX/XX

1st Brigade, 4th Infantry

1-66 Armor Bn — Total Number of Vehicles On Hand: XXX
Disabled Vehicles: XXX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX

3-66 Armor Bn — Total Number of Vehicles On Hand: XXX
Disabled Vehicles: XXX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX

2nd Brigade, 4th Infantry

1-67 Armor Bn — Total Number of Vehicles On Hand: XXX
Disabled Vehicles: XXX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX

3-67 Armor Bn — Total Number of Vehicles On Hand: XXX
Disabled Vehicles: XXX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX

3rd Brigade, 4th Infantry

1-68 Armor Bn — Total Number of Vehicles On Hand: XXX
Disabled Vehicles: XXX
Vehicle ID: XXXXXXXXX Disabled since: XX/XX/XX

Figure 15 Sample Current Status of Fielded Vehicles Report

b) Failure Analysis by LRU

This sample report (Figure 16) shows the number of LRU failures for each vehicle within a Major Command. The report further identifies the individual vehicles and shows the number of days the LRU, and in turn, the vehicle, is considered NMC.

LRU Failure Analysis Report

Command: 4ID

Date: XX/XX/XX

LRU	Veh ID	Vers #	Date Failed	Total Days
CID				
	XXXXXX	XX.XX	XX/XX/XX	XXX
	XXXXXX	XX.XX	XX/XX/XX	XXX
CITV				
	XXXXXX	XX.XX	XX/XX/XX	XXX
	XXXXXX	XX.XX	XX/XX/XX	XXX
	XXXXXX	XX.XX	XX/XX/XX	XXX
DECU				
	XXXXXX	XX.XX	XX/XX/XX	XXX
DID				
GCDP				
	XXXXXX	XX.XX	XX/XX/XX	XXX
FCEU				
	XXXXXX	XX.XX	XX/XX/XX	XXX
HEU				
IFCEU				
	XXXXXX	XX.XX	XX/XX/XX	XXX
POS/NAV				
TEU				

Figure 16 Sample LRU Failure Analysis Report

c) Failure Analysis by Troubleshooting Procedures

The following sample report (Figure 17) shows the number of failures by troubleshooting procedure number for each vehicle within a Major Command. The report further identifies related TP # failures and shows, for the specific failure, the date the failure occurred. This date *is not necessarily* the date the vehicle is considered NMC since the vehicle may have been rated NMC prior to identifying the failed TP #. I.e., there might be a failure in an LRU and, after replacement of the LRU, the FIT identified a second LRU problem.

Troubleshooting Procedures Failure Analysis Report

Command: 4ID | Date: XX/XX/XX

TP #	Veh ID	Related TP	Related TP	Related TP	Date Failed
NNN	XXXXXX	NNN	NNN		XX/XX/XX
NNN	XXXXXX				XX/XX/XX
NNN	XXXXXX	NNN	NNN	NNN	XX/XX/XX
	Total failures for TP # NNN:		NNN		
NNN	XXXXXX				XX/XX/XX
	Total failures for TP # NNN:		NNN		
NNN	XXXXXX				XX/XX/XX
NNN	XXXXXX	NNN	NNN	NNN	XX/XX/XX
	Total failures for TP # NNN:		NNN		

Figure 17 Sample TP Failure Report

d) Failure Analysis by System Versions

The following sample report (Figure 18) shows failures that occur within a vehicle loaded with a specific system drop of software. When compared to the previous system drop, it will help to identify which software failures were resolved and which were introduced. The latter may occur when a problem is masked due to another problem. Once that other problem is resolved, the second problem can be identified and resolved. The report will contain entries for all system drops currently fielded.

System Drop Failure Analysis Report

Command: 4ID | Date: XX/XX/XX

System Version Number: XXX.XXX

LRU	LRU Vers	Veh ID	Date Failed	Total Days
NNN	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN
NNN	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN

System Version Number: XXX.XXX

LRU	LRU Vers	Veh ID	Date Failed	Total Days
NNN	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN
NNN	XXX.XXX	XXXXXX	XX/XX/XX	NNN
NNN	XXX.XXX	XXXXXX	XX/XX/XX	NNN
	XXX.XXX	XXXXXX	XX/XX/XX	NNN

Figure 18 Sample Failure Analysis by System Versions

V. CONCLUSION

The enhancements proposed in this thesis have been recognized by the Associate Director of the Next Generation (NextGen) Software Engineering Center, RDECOM - TARDEC for their potential to quantify and resolve low-level software and hardware issues. This concept has been submitted as a proposal to become a Department of Defense Small Business Innovation Research (SBIR) Program.

A. VALUE ADDED

Current reports can identify a vehicle classified as NMC. They cannot further identify the LRU that is the cause of the failure. That information might be available from examining logistical spare parts orders for the unit but if the wrong LRU is ordered, that information is not accurate either. This is somewhat trial and error, and prevents any accurate trend analysis from being performed at the major command level. Also, historical data for operational readiness is not being maintained. That means the Major Command may review the current status of its vehicles, only.

Having the additional information contained in the Master Fault Database will allow statistical trends to be reviewed and will allow commanders to maintain better control when ordering replacement LRUs.

Implementing the new database systems will continue to allow Tank Commanders (TCs) and their chain of command to use their best judgment on the operational readiness of a vehicle. At the same time, it will enable them to capture important information that will improve the state of their repair parts, and ultimately, improve the quality of the vehicle's hardware and application and test software.

B. CHALLENGES AND OPPORTUNITIES

1. Safety Critical

System Safety is always a major concern. From a top-level view, a major command expects its units to be combat ready based on the URI for each unit. With more detailed reports available, the chain of command can better manage their units in preparation for their primary duty -- to engage the enemy.

From the unit's viewpoint, resolving problems with faulty LRUs and having sufficient numbers of spares available is certainly optimal.

Addressing reasons for failure, situations where the test might be masking more serious problems, will hopefully save crewmembers' lives.

2. Difficulty in Gaining Acceptance

During an interview with a former Tank Commander, SFC Tom Davis, retired, SFC Davis said the majority of all faults are documented on a daily basis, on the vehicle's DA Form 2404 (Equipment Inspection and Maintenance Worksheet). It is in the best interest of the vehicle's crew to ensure that the vehicle is fully operational at all times. Crewmembers want to see all faults identified and corrected, and an appropriate level of spares maintained. It is their livelihood and their lives at stake. The problem of overriding the readiness status appears to be at the company and/or battalion level. That is where the Circle-X's are being used. The challenge then is to allow personnel at those levels to override the report while getting them to provide explanations.

This challenge can be addressed by reporting the additional information at the top level of the chain of command and then have that report flow back down the chain. Once management at the lower levels observes that upper-management is viewing this information in the new reports, there will hopefully be a better flow of communication at all levels.

SFC Davis identified a second challenge: crewmembers are constantly busy with the current amount of daily requirements. He suggests that there may be resistance to the process caused by adding another requirement, to enter the reason for the fault into the database, to their workload. Once they see an increase in the attention spent on improving the operational readiness of the vehicles, this resistance should be overcome.

3. Incorporation on Legacy Vehicles

Because of budget constraints, incorporating this process into legacy systems may prove to be the greatest challenge. The Program Executive Office for the legacy vehicle will need to add the development of the database software; training for the new system; new processes developed for performing trend analysis; etc. into the vehicle's budget.

Since the majority of available funding is already designated, this process will need buy-off at all levels.

4. Incorporation on Future Force Vehicles

Since there hasn't been any precedence set for the new vehicle, incorporating these new processes should be much easier. The additional features outlined by this research as essential for improving the current Unit Readiness Index reporting procedures can be incorporated into initial system design. Features such as automatically recording data into the vehicle database, and automatically modifying the number of spares required by command (based on an automated specific trend analysis to gauge projected failures based on the number of current and previously reported failures) can be built in and prevent the continuation of the current Operational Readiness reporting problem.

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